THE GLACIATION OF NORTH CENTRAL CANADA.[1]

I WISH very briefly to place before you a statement of what would seem to me to have been the conditions that prevailed during at least part of the glacial period in the great Central Plains region of Canada, but before going farther I take great pleasure in acknowledging my indebtedness to Professor Chamberlin, Mr. Warren Upham, and many other glacial geologists of the United States, whose work is so closely connected with mine, and who have so clearly expounded many of the principles on which my explanations are based. It is an especial satisfaction to me to feel that the results of my investigations accord so well with theirs.

In the preparation of the slides here shown I have freely used the published works of these geologists, and of Dr. Dawson and Messrs. McConnell, Low, and of our own geological survey, when depicting the conditions that prevailed in those portions of the country which have not come under my own personal observation.

That portion of Canada, to which I propose to refer for a few moments, lies between west longitudes 85° and 130°, and north latitudes 49° and 69°; or perhaps it may be more intelligibly located as being bounded on the east by the west coast of Hudson Bay, and a prolongation of the same line southward, and on the west by the Rocky Mountains, the average distance between these two lines being about 1100 miles; on the south by the international boundary, and on the north by the Arctic Ocean, which are an average distance apart of 1400 miles, giving a total area of about 1,500,000 square miles.

This vast region has a remarkably even surface contour, with a mean elevation above the sea of about 1200 feet, and slopes gently from the foot of the Rocky Mountains northeastward to

[1] Read at the Toronto meeting of the British Association, August 1897.

Hudson Bay. The contour lines here shown are respectively 600, 1500, and 3000 feet above the sea, and from the 3000 feet contour line the surface has an average slope of a little less than three feet to the mile. This slope is of course not quite regular, being broken by hills and valleys, and occasionally the country rises for some considerable distance in the opposite direction, but on the whole the general decline is very well marked, and no high mountains break the general monotony of the landscape.

In the more northern portion of the region are the treeless plains, or "Barren Lands," extensive level or undulating grassy plains, with a mean summer temperature below 50° F., and with a frozen subsoil which prevents the growth of trees. South of this is the great forest region, the home of the chief fur-bearing animals of Canada, and still farther south are the plains or prairies, which many of you will probably cross on the transcontinental railways after the close of this meeting.

It would be beyond the scope of this paper to discuss the question of rainfall, but suffice it to say that the humidity of the atmosphere decreases from the seacoast inland, and while the Barren Lands are kept constantly wet by fogs and drizzling rains, the air over the prairies is very dry, and licks up rapidly any moisture that may be lying on the surface of the ground.

As you will see from the handbooks prepared for the use of the members of the association, the northeastern part of this region is underlain by crumpled and distorted Archæan rocks, whose surface has, even in pre-Cambrian times, been reduced to an undulating plain, with very slightly accentuated contours. On each side of this elongated area, or low central ridge, of highly altered Archæan rocks, are flat-lying limestones, sandstones, and shales, varying in age from the Cambrian up to the Tertiary, and separated by several erosion intervals, which, with the water-deposited strata, would indicate a gradual rising and lowering of the land along a line parallel to the present Archæan outcrop. From a study of the Rocky Mountains, and the mountainous region of British Columbia,[1] Dr. Dawson has shown rea-

[1] On the Later Physiographical Geology of the Rocky Mountain Region in Can-

sons to believe that the oscillations of the land were exceptionally rapid in early glacial and immediately preglacial times. But it would seem probable that the drainage has always followed the main valleys which still trench the surface, running more or less at right angles to the mountains.

The pre-Cambrian valley of Chesterfield Inlet, extending eastward towards Hudson Strait, and westward towards Great Slave Lake, and the post-Cretaceous valley of the Saskatchewan, extending towards the lower valley of the lower Nelson River, and many other valleys running more or less parallel to these, go to prove the general correctness of this statement.

In the opinion of the writer almost all of this country was overspread by the Keewatin glacier, which centered in what is now the comparatively low country west of Hudson Bay. Evidences of its presence may be seen almost everywhere in striated rock surfaces, giant's kettles, widespreading sheets of unstratified till, stratified inter-till deposits, moraines, eskers, and transported bowlders.

The causes of the great cold of the glacial epoch are yet enshrouded in mystery, and the most that has been suggested is that if such and such things had been so, if the land had been higher here or lower there, ice would have accumulated in northern latitudes, but as yet there is little or no proof that such conditions did exist. At present it would appear to be much more satisfactory to spend our energies in endeavoring to follow up the traces left by the glaciers and lakes of the glacial epoch, and to first determine the conditions that existed at one time, or the order in which certain conditions existed, rather than to devise elaborate theories to account for conditions that may never have occurred. When the country has been thoroughly examined, and the glacial deposits, striæ, etc., are well known, the proximate causes of these phenomena will in all probability be easily determined.

The information with regard to the conditions of glaciation

ada, by GEORGE M. DAWSON, Trans. Roy. Soc. Can., Vol. VIII, Sec. 4, pp. 1–74. Ottawa, 1890.

unearthed is undoubtedly but a very small portion of what will be known when our country is more fully explored, for compared to the vastness of the field and the probable extent of the harvest of knowledge, the harvesters are indeed very few. The observations here discussed have been made by the writer during the past thirteen years, but as individual records are difficult to grasp and remember, I have attempted to connect them in such a way, and to bring them graphically before you, so that you may form a clear idea of the results that have been attained, and at the same time I shall endeavor to state very briefly some of the evidence on which those results have been based, so that you may distinguish between the records and the connecting theories.

Up to the present time three great continental glaciers have been recognized in Canada, viz., the Cordilleran, which covered the western mountains and their intervening plains, from latitude 49° to latitude 66°; the Keewatin, which covered the great plains east of the mountains; and the Labradorean, which spread over northeastern America from a center in Labrador.

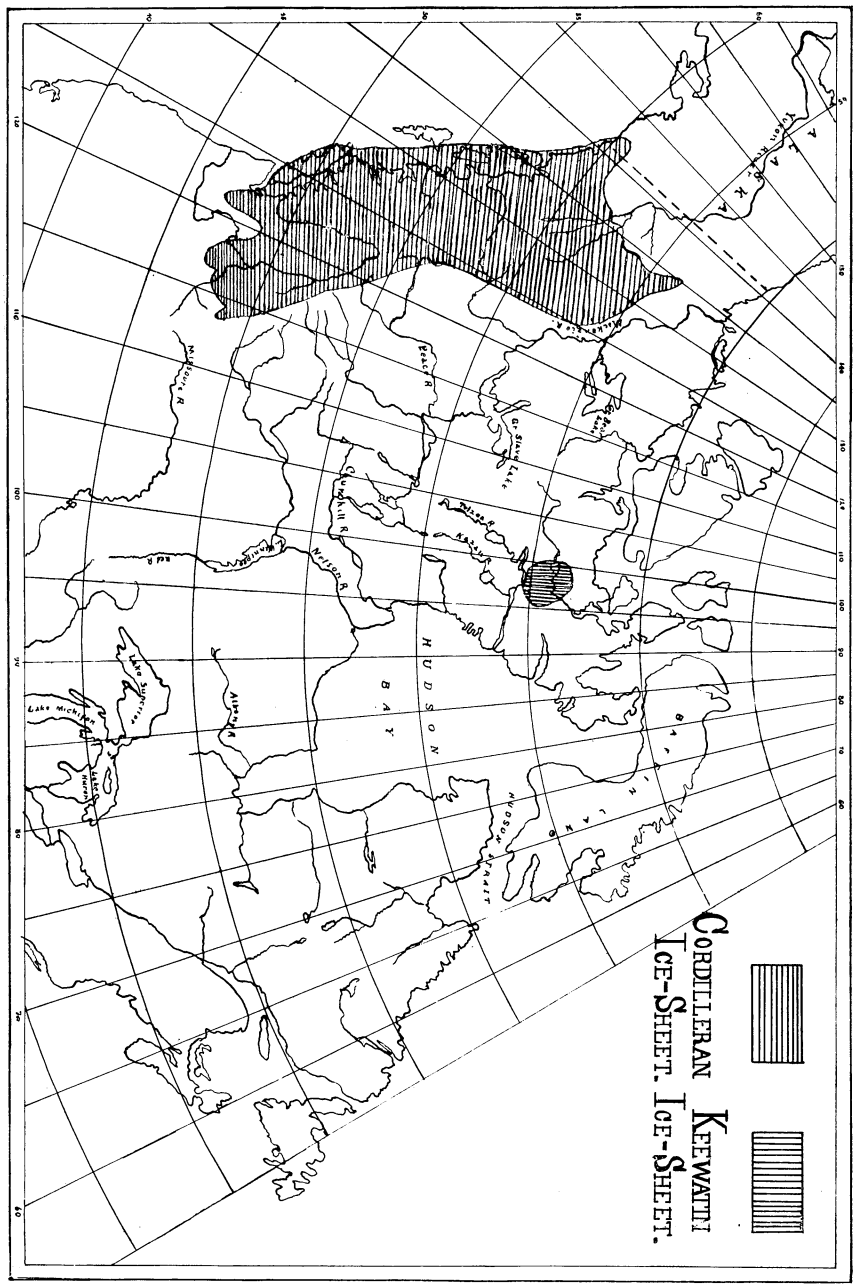
The earliest till as yet recognized in Western Canada, east of the Rockies, has been called by Dr. Dawson the Albertan Deposit,[1] and has been shown by him to have been formed by tongues of the Cordilleran glacier, which extended outwards towards the plains through the transverse valleys of the Rocky Mountains.

The illustration shows the greatest extent of this Cordilleran glacier as defined by Dr. Dawson.

From the fronts of these glacial tongues streams rushed eastward, carrying with them large quantities of coarse detritus which were soon deposited in the bottoms of the valleys as beds of coarse, well-rounded gravel, called by Mr. McConnell the Saskatchewan gravel, this gravel and the Albertan till being directly traceable into each other.

The Cordilleran glacier then withdrew; but whether it entirely

[1] Glacial Deposits of Southwestern Alberta, by GEORGE M. DAWSON and R. G. MCCONNELL, Bull. Geol. Soc. Am., Vol. VII, p. 66, Rochester, 1895.


CORDILLERAN
ICE-SHEET.
KEEWATIN
ICE-SHEET.
HUDSON
BAY
LABRADOR
PEACE R.
NELSON R.
CHURCHILL R.
SASKATCHEWAN R.
WINNIPEG
LAKE WINNIPEG
LAKE MICHIGAN
LAKE SUPERIOR
ATHABASCA
GR. SLAVE LAKE
GR. BEAR LAKE

disappeared, or merely confined itself to the west side of the Rocky Mountains, I do not know, but at all events it seems to have ceased to be an important element in molding the features of the plains.

After the withdrawal (or possible disappearance) of the Cordilleran glacier, the Keewatin glacier overspread the country, radiating outwards from a center probably lying somewhere between Doobaunt and Back rivers. The till formed during this period, which is probably synchronous with that of the sub-Aftonian period of Professor Chamberlin, may be easily recognized in the scarped banks of many of the streams in Alberta, where it overlies the Saskatchewan gravel of the Albertan period. It is composed largely of material derived from the underlying Cretaceous and Laramie rocks, but at the same time it contains a considerable quantity of other material transported from a distance, some of which, consisting of granite, gneiss, quartzite, and similar rocks, has been derived from the Archæan nucleus to the northeast, while some has been derived from the Cambrian sandstones, and Cambro-Silurian and Silurian limestones that extend around the edge of the Archæan.

After the deposition of the sub-Aftonian till the Aftonian period of deglaciation set in, during which the Keewatin glacier became greatly diminished, and interglacial deposits were laid down, both in extraglacial lakes, and in lakes and swamps at some distance from the face of the glacier. How far the foot of the glacier withdrew in this interglacial time I do not know, but I am inclined to think that most of Manitoba still remained covered with ice, for in the western part of that province I have not been able to find evidence of more than one main Keewatin interglacial period, which is probably later than the Aftonian period.

After this period of diminution the Keewatin glacier again began to increase, and it spread southward and westward until it had reached about the same limits that it had reached during the sub-Aftonian period, and had spread another sheet of till over the earlier till and subsequent interglacial deposits. The

period of this advance of the ice would seem to correspond to the Kansan epoch, as at present understood by American geologists. This till is very similar to that below it, but the material of which it is composed is more highly oxidized and decayed, and fragments of soft, brittle rocks, such as lignite, are much less common in it than in the lower till.

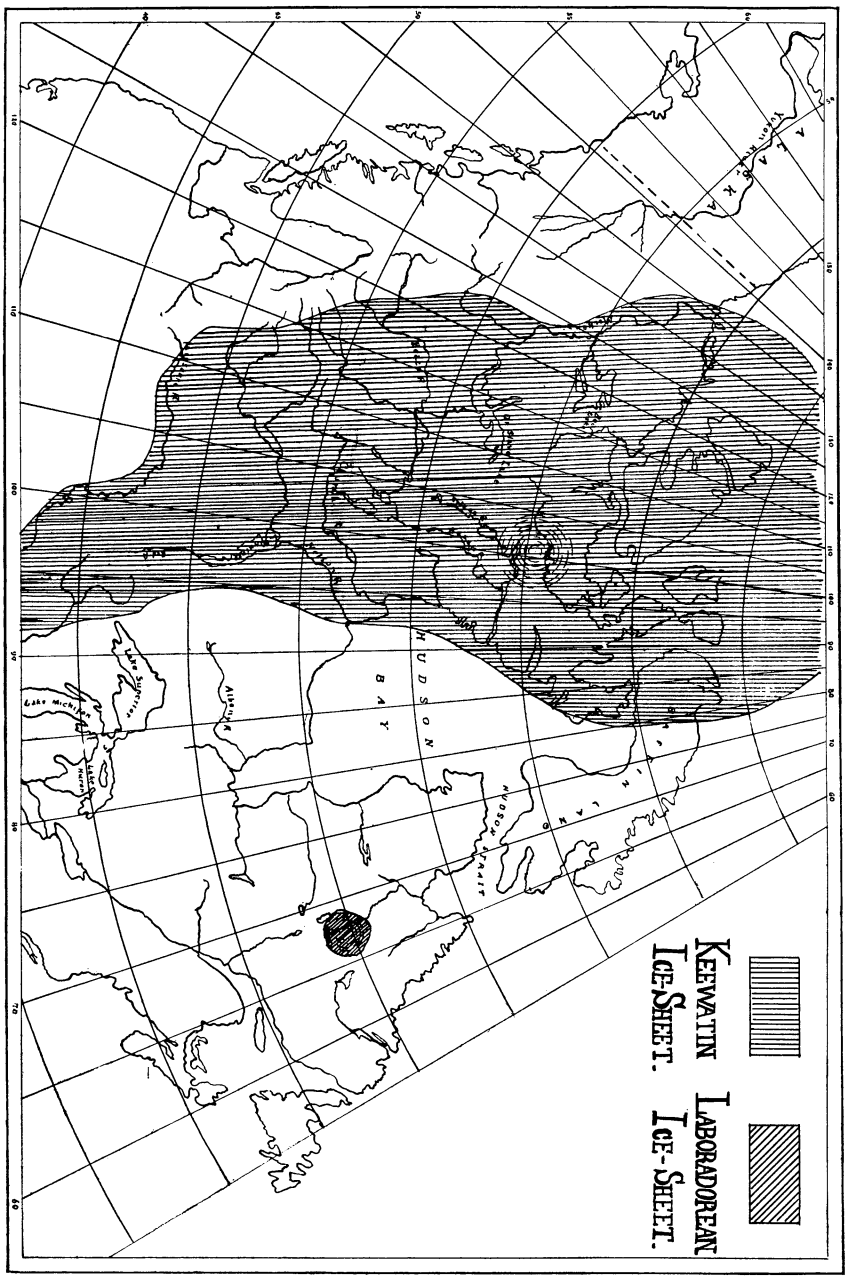
Both during the Kansan and sub-Aftonian epochs, extraglacial lakes of greater or less size doubtless existed, and any material brought down into them by the glaciers would doubtless have been scattered over their floors or along their sides. Thus bowlders were probably carried some distance beyond the extreme limits to which the glaciers themselves reached, as, for instance, on some of the terraces near, and at the foot of the Rocky Mountains where Dr. Dawson has recorded the occurrence of numerous transported bowlders. Where these lakes existed terminal moraines would also not be found, and thus the absence of terminal moraines may often be explained in places where we should otherwise expect to find them.

Striæ have not been recognized in this western district, for the soft Cretaceous rocks are not suitable for their preservation, but the older and harder rocks, nearer the center of the glaciated area, are everywhere scored with glacial markings. Around the periphery of this area underlain by harder rocks I have not been able to recognize more than one set of striæ referable to the Keewatin ice-sheet or rather more than one direction of striation, but nearer the glacial center several sets may be distinctly seen. Along the Doobaunt River above the Forks the oldest of these point southward, probably running outwards from a center between Doobaunt and Back rivers. These I have associated with the earlier stages of the Keewatin glacier, though I have no direct evidence to offer on that point, except that they are the earliest of four different and distinct sets of glacial striæ.

The accomplished geologists who have worked in the United States, near the headwaters of the Mississippi River, have found that there was an extended epoch of deglaciation after the deposition of the Kansan till, and I would assign to this interglacial

epoch a line of division in the till of western Manitoba, along which stratified deposits may occasionally be seen, but which is strongly marked in several places by beds of bowlders that have been sunk in the surface of the earlier till, and being there held firmly in place have been smoothed and striated by the later glacier which passed over them. How far the Keewatin glacier retreated during this second epoch of deglaciation is not known, but it is not improbable that it withdrew far north of the present northern boundary of Manitoba.

After this interglacial epoch the Keewatin glacier again began to increase, though its center of dispersion had gradually shifted southeastward until it now rested over the country between Doobaunt and Kazan rivers. From this center it flowed outwards in all directions, and its striæ may be seen on most of the rocky knolls throughout that whole northern country, running southward towards Lake Winnipeg, westward towards the Mackenzie River, northward towards the Arctic ocean, and eastward towards Hudson Bay. Everywhere the smooth-faced hills give evidence of its presence, and even in the absence of striæ, the evenly-rounded surfaces facing the glacial center, and the broken, craggy hills looking in the opposite direction, furnish convincing evidence of the direction of flow of the ice. As the glacier advanced southward it came in contact with the high escarpment of Cretaceous shales forming the Porcupine and Duck mountains in Manitoba, and part of it was diverted to the east of south along the great valley of Lake Winnipeg. This lobe appears to have extended southward into Minnesota, Dakota, and Iowa, and to have deposited a till which probably corresponds to what Professor Chamberlin has called the East Iowan Formation. The Palæozoic limestones of western Manitoba have been beautifully scored by the markings of this glacier, and its grooves and striæ were detected in many places around the shores of Lake Winnipeg. East of the shores of Lake Winnipeg the exposed surfaces of the Archæan rocks were carefully searched for this set of markings, but none could be detected. It therefore seems probable that the eastern edge of this lobe or portion of


KEEWATIN ICE-SHEET.
LABORADOREAN ICE-SHEET.
HUDSON BAY
LABRADOR PENINSULA
JAMES BAY
LAKE SUPERIOR
LAKE MICHIGAN

the Keewatin glacier did not extend very far east of the present eastern shore of Lake Winnipeg, and it is also probable that throughout its advance there was a free drainage eastward into Hudson Bay.

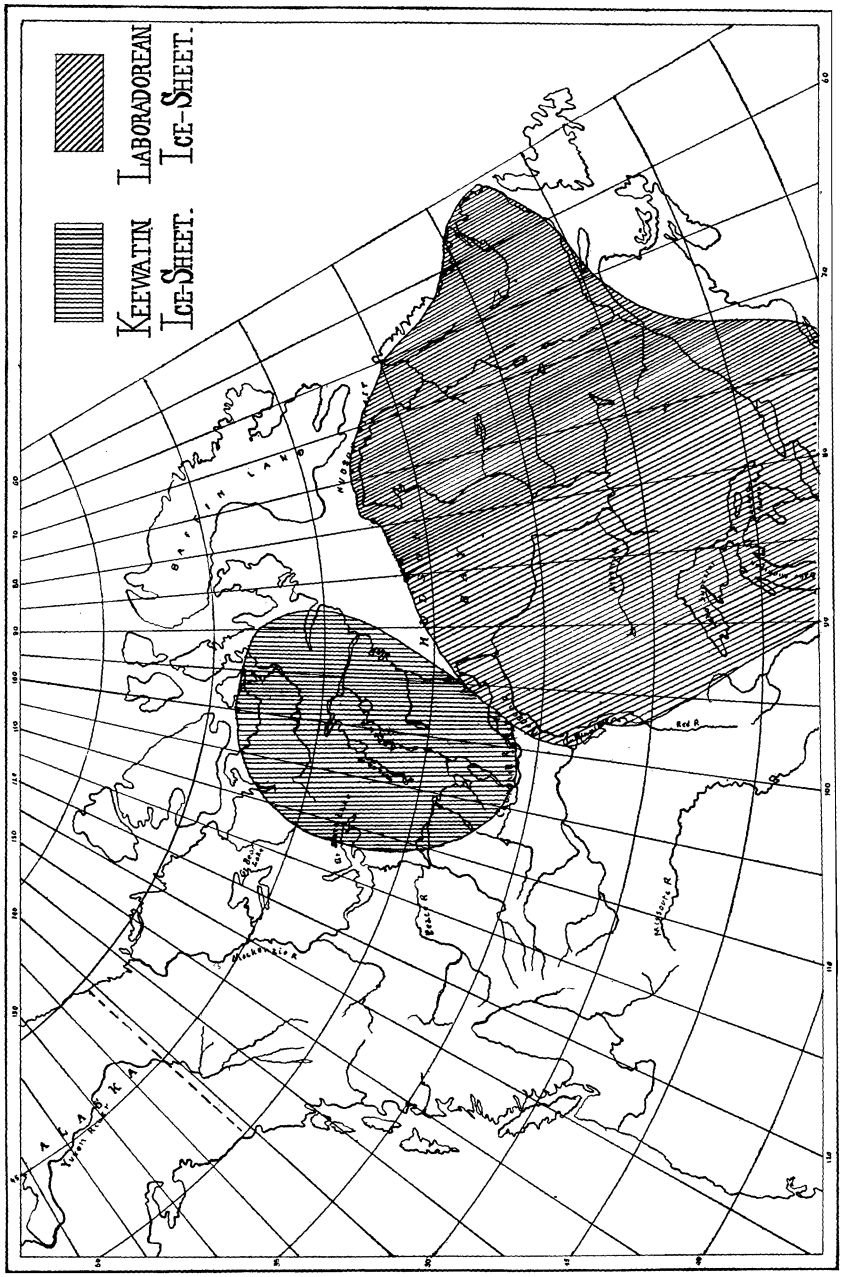
Traces of the existence of the streams that flowed eastward from the face or side of this glacier were found in several places in the form of deep potholes or giant's kettles, excavated in the summits or on the eastern slopes of knolls of granite, and gneiss where they could not have been formed under present conditions. At one place, on the south side of Berens River, several of these potholes occur on the east side of a granite knoll, one of them, at least, being ten feet in depth, and about thirty inches in diameter from top to bottom. The ten-foot hole was cleaned out, and was found to contain a great many rounded pebbles, all of Archæan rocks, some similar to the rocks of the surrounding country, and others that had evidently been transported from a distance. Both this and most of the other rocky hills where potholes were seen, have been scored and scraped down by the later glacier from the east, the outer sides of some of the holes having been cut away, leaving rounded niches in the faces of the smooth hillsides.

While a portion of the Keewatin glacier flowed southward in the Winnipeg basin, another parallel glacial stream would seem to have traveled southward between the Porcupine and Duck mountains on the east, and the rising land now marked by the Missouri Coteau on the west, both sides of this wide shallow depression being now at elevations of about 2200 feet above the sea. This glacial lobe probably extended southward into Dakota, and at its greatest extension it coalesced with the Winnipeg lobe over the summits of the Porcupine and Duck mountains, but for long periods, doubtless when the glacier was both advancing and retiring, the two lobes were more or less separated, and an extensive interlobate moraine was deposited on the summits of these hills. The Missouri Coteau is also considered to be the great moraine deposited along the west side of this lobe of the Keewatin glacier. Whether the glacier extended west of

the Missouri Coteau during this period is uncertain, but there is a strong morainic ridge extending from the Hand Hills northwestward by Sullivan Lake to the Beaver Hills, which may have been formed at this time. A high, stony, lumpy ridge about the same elevation as the Missouri Coteau, and north of and more or less parallel to the Saskatchewan River, between it and the Beaver and Athabasca rivers was doubtless formed a little later in the same glacial epoch.

Now, confining our attention to the Winnipeg lobe of the Keewatin glacier we find that after reaching its greatest extent in a southeasterly direction it gradually retired northward, and as it retired a portion of the Laurentide glacier which had accumulated in the country farther east, perhaps on the high land of the Labrador peninsula, advanced and the fronts of the two united. The Keewatin glacier had probably retired well north into Manitoba, and possibly beyond the northern confines of that province, before it was joined by the eastern glacier. After they had united the water formed by the melting of the two glaciers was ponded between their fronts and the high land to the south and west, and a large extraglacial lake was formed, which has been called by Mr. Upham Lake Agassiz.

As the Keewatin glacier retired still farther, the eastern portion of the Labradorean glacier continued to advance and obliterated most of the marks left by its predecessor, but here and there, on the harder rocks on the east side of Lake Winnipeg and farther north, distinct cross striæ were observed, where the later glacier had not rubbed out all the earlier grooves and striæ. The later glacier reached to the west side of Lake Winnipeg, or in some places a little beyond, its front assuming a roughly lobate form. Near the mouth of the Saskatchewan River the till formed by both glaciers is well shown, but between the two is a thickness of 12 feet of stratified sand and clay, showing that the Keewatin glacier had retired northward for a sufficiently long time before the advent of the Labradorean glacier to allow of the deposition of this thickness of water-lain lake-deposits.


KEEWATIN ICE-SHEET.
LABORADOREAN ICE-SHEET.
HUDSON BAY
HUDSON STRAIT
BAFFIN LAND
ALASKA
YUKON R.
MACKENZIE R.
GREAT BEAR LAKE
GREAT SLAVE LAKE
PEACE R.
ATHABASCA R.
SASKATCHEWAN R.
RED R.
ASSINIBOINE R.
MISSOURI R.

Two hundred miles still farther north, along the Grass and Burntwood rivers, the striæ of the two glaciers cross almost at right angles to each other, the one being clearly later than, and independent of, the other. A little farther east, north of Gull Lake and Nelson River, is a long narrow sandy esker, from 90 to 200 feet in height, running east and west, clearly formed by one of the streams draining the Labradorean glacier. This ridge of loose sand would certainly have been swept away, if any glacier had advanced from the north subsequent to its formation.

Before the fronts of the two great glaciers had separated the eastern one had again begun to retire, and as it retired a thickness of from 50 to 100 feet of stratified clays and silts were deposited in the bed of Lake Agassiz, chiefly north of the present basin of Lake Winnipeg, for there some large streams draining the Labradorean glacier discharged into the lake, bringing with them a heavy cargo of glacial mud. The positions of these streams are still marked by long and high eskers, which may be seen near the banks of the Nelson River, crossing the country in a direction parallel to the later striation.

The Nelson River, in its northern course, from Playgreen Lake to Split Lake, marks the approximate eastern limit of this deposit of stratified clay, and along the eastern shores of Lake Winnipeg the stratified clays were not found at a greater height than 150 feet above that lake, and, except at one place, at no great distance back from its shore.

The absence of these stratified deposits would tend to show that the eastern glacier had not retired to any considerable distance east of Nelson River and Lake Winnipeg, before Lake Agassiz was drained by the gradual shrinkage of the Keewatin glacier to a small area in the vicinity of Doobaunt and Yath-kyed lakes.

Subsequently the Keewatin glacier appears to have broken into two or more smaller glaciers, the centers of which lay still nearer the coast of Hudson Bay than the center of the single glacier. One of these centers rested over the hills southeast of Yath-kyed Lake, and from it the ice radiated in all directions,

while another probably rested over the country north of Baker Lake and Chesterfield Inlet. Even at the present day it would take but a slight reduction in temperature, or a slightly greater precipitation, to cause that northern country to be covered with snow, for in the middle of August heavy patches of snow were seen resting on many of the hillsides and Doobaunt Lake was almost completely covered with a thick sheet of ice.

After the glaciers had been greatly reduced, or had entirely disappeared, the land west of Hudson Bay stood about 500 or 600 feet below its present level, and subsequently it gradually rose until it reached its present condition of comparative stability.

Whether the three great glaciers here referred to, namely, the Cordilleran, the Keewatin and the Labradorean, originated at the same time or not I do not know, and whether they waited for one another's disappearance or not I do not know; but this much appears certain that the Cordilleran glacier had reached its greatest extent and had retired, before the Keewatin glacier reached its extreme western limit; and that the Keewatin glacier, after covering the Plains region of central Canada for a great length of time, had retired a long distance toward its central gathering ground, before the Labradorean glacier reached its utmost western limit, and that it had shrunk to a very meager representative of its former greatness, when the latter glacier was still of magnificent propositions.

J. BURR TYRRELL.